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CHEMICAL ENGINEERING DEVELOPMENTS IN THE ELECTRICAL FIELD

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ALTHOUGH we all use the term "engineering" very glibly, most of us would be unwilling to guarantee a perfectly satisfactory definition. The dictionary definition is far from complete: "the art and science by which the mechanical properties of matter are made useful to man in structures and machines." And the definition of Chemical Engineering is only slightly less restricted in its scope, i. e., "concerned chiefly with the preparation of the materials used in industrial chemistry, the design and erection of the necessary plant, etc." The most difficult of all is to define the term "chemical." What are chemical actions and what are physical? It is easy to give an example of reactions which are chemical and equally easy to cite instances of actions which are purely physical in their nature, but what sort of an action is the absorption of a gas by charcoal, or the emission of electrons from heated metals or oxides, or even the change in optical properties of a celluloid midel under stress? It would seem that when a metal or an oxide is so seriously disturbed as to give up some of the very bricks out of which the atoms are built, or a transparent material so changed from its original condition that polarized light is split up into various wave-lengths, something of a pretty intimate character must have happened. However, if we claim that the operation of a vacuum tube and the study of photoelasticity are chemical processes, we are liable to be accused of attempting to cover too much territory. It is generally true that the boundary line between chemistry and physics is a changing one, depending on the relative numbers and pugnacity of chemists and physicists taking part in the discussion.

The major points of contact of the chemist with the industry are in connection with materials and processes and the necessities of design and invention. It is the pressure due to the need of the industry for new and better materials, and improved methods of performing old operations, which furnishes the stimulus for much of the creative work of the chemical engineer.

The history of the incandescent lamp is a case in point. The old carbon filament light at first required five watts per candle power and after a great deal of refinement, this was brought down to three watts candle. It was known that if the filament were heated to a higher temperature, the efficiency could be greatly increased. Unfortunately, however, raising the temparature materially above the normal figure shortened the life of the lamp to such an extent that the increased cost of renewals more than offset the gain in efficiency. As a result of considerable study the "Gem" or graphitized filament lamp was produced. This was capable of being operated at considerably higher temperatures without unduly shortening the life. However, even this lamp required 2½ watts per candle power. As a result of further investigations, the squirted tungsten filament was produced. This filament gave greater efficiency, but owing to the fact that it was composed of more or less discrete particles of metal, slightly sintered together, was very fragile. The brilliant researches on ductile tungsten carried on by Coolidge and his associates resulted in a filament which not only gave the good efficiency of 1½ watts per candle, but was very rugged in addition. Whitney next demonstrated that by filling the tube with an inert gas, it was possible to operate the filament at a much higher temperature without undue volatilization of the filament and thus still further increase the efficiency. As a result of this work, the modern gas-filled lamp was developed, the larger sizes of which have an efficiency of .75 watts per candle.

The lead wires of the present-day bulb represent another piece of engineering which was stimulated by the needs of the industry. The earliest lamps had seals of platinum through the glass, and this practice continued until only a few years ago. These seals were quite satisfactory and the amount of platinum in each lamp being very small, the cost was not excessive. However, with the rise in the price of platinum, and the increasing demand for platinum in the chemical inrustries, a need was felt for a base metal sealing-in wire. The requirements were that the wire have approximately the same coefficient of expansion as the glass into which it was to be sealed, and that the softened glass should wet the wire. As is well known, the iron-nickel alloys have a range of expansion coefficients from practically zero to that of nickel. However, glass does not wet this material very well. It had also been known that glass would wet copper, making a real seal, particularly if the copper were slightly oxidized during the process.

A combination of these two materials, in which an iron nickel core of the composition to give the proper coefficient of expansion, and a sleeve of copper, integral with the core, was produced by surrounding a rod of iron-nickel with a jacket of brass, and after slipping over a tube of copper, heating to the melting point of the brass and rolling while hot. These combination rods were then drawn into wire, which is the "dumet" wire used in all incandescent lamps as well as most radio tubes.

A recent chemcial engineering development in the electrical industry is in the field of transformer engineering. In spite of the improvements which have been made in the refining of transformer oils, continued operation of large transformers with an air space above the oil produces oxidation and sludging. This sludge settles on the windings and cooling coils and prevents the dissipation of heat, so that the temperature rises too high thus producing more sludge. A further effect is to lower the insulating value of the oil. This does not happen all at once and the harmful results of sludging can largely be avoided by filtration. This, however, is a tedious and rather expensive operation. Furthermore, if an arc is formed below the oil, due to some mischance which is not supposed to happen, but nevertheless sometimes does, relatively large volumes of hydrogen and methane, together with smaller amounts of CO_2 and other hydrocarbons are liberated. These form an explosive mixture with the air above, and when the arc reaches the surface, a disastrous secondary explosion occurs. Filling the transformer case completely with oil and providing an expansion tank to take care of the change of volume when the oil heats and cools due to load changes, partially prevents this type of explosion, but at the same time removes the one valuable feature of a gas space above the oil, i. e., the cushioning effect of the gas when primary explosions caused by arcs take place. The obvious way to prevent sludging and secondary explosions, and to minimize the effect of the original disturbance, is to keep a cushion of inert gas above the oil. Intensive work over a period of two years has resulted in the Inertaire Transformer, in which the air above the oil is first swept out with nitrogen, and subsequent breatheing forced to take place through a mixture of finely divided copper, ammonium chloride, kieselguhr and calcium chloride. This effectually removes the oxygen from the air breathed in and maintains an inert atmosphere above the oil. Development of the characteristitc robin's egg blue color in the used material tells the operator how much of the charge is spent, the line of separation between the new and spent material being very clearly seen through the glass container. The residual nitrogen then passes through calcium chloride to dry it and remove traces of annomia. This combination of an oxygen absorber which is effective at all temperatures and rates of flow met with in practice, and a dehydrator which guarantees the dryness of the transformer atmosphere, is one of the big steps forward in the industry, and gives the operator a sense of security hitherto lacking in transformer operation.

A line of activity which is not as spectacular as that of invention relates to the work on materials and processes. The fundamental materials with which the electrical industry is concerned, while extremely varied, may be roughly divided into six classes on the basis of their use, although overlapping is bound to occur due to the fact that a given material may simultaneously perform more than one function. For purposes of discussion, the following classification will serve as well as any:

1. Electrical conductors.
2. Electrical insulators.
3. Magnetic materials.
4. Structural materials.
5. Lubricants.
6. Protective coatings.

In addition to these materials, which enter into the finished product, a host of miscellaneous items, ranging from fuels to typewritten ribbons, require checking up, specifying, and in many cases improving.

When the subject "electrical conductors" is mentioned, the mind usually turns to copper, and, indeed it has been the needs of the electrical industry more than any one thing which have provided the driving force which has resulted in modern methods of copper refining. As you all know, copper of the highest purity is not required for many purposes, but the presence of minute traces of impurities lowers the conductivity of copper so largely that it cannot be used in modern electrical apparatus. In addition to a high conductivity, copper which is to be subjected to the extremely severe cold working received in making edgewise wound coils, must have very high ductility, and here again the chemical engineer has been invaluable in determining what impurities are permissible, and how much oxide is necessary to produce the proper degree of ductility.

Many other applications, however, require an electrical conductor having a resistance many times that of copper. Here again the chemical engineer has done his bit in furnishing alloys all the way from the 15% conductivity metal used for collector rings of induction motors, to the alloys of the nickel-chromium type, having resistances 50 to 60 times that of copper and capable of operating at high temperatures for very long periods. In addition to the actual magnitude of the resistance of such alloys, the temperature coefficient of resistance is of great importance, as in measuring instruments of nearly all kinds, the accuracy of the readings should be the same at all temperatures of use. This need has resulted in the development of such well known materials as magnanin and advance, and only recently in the production of "negatan," having a negative coefficient. This promises to be useful in combination in the other wires for producing a true zero coefficient resistance.

Insulating material is a problem which, like the poor, is always with us. This work has taken two general directions: one towards improving motor and generator insulation so that the machines may be run safely and continuously at higher temperatures, and the other directed towards producing materials capable of withstanding very high voltages. The need for the first class of improvement is not apparent at first glance, as it might be thought that machines of this type should be so designed as to give small heat losses. The facts are, however, that increasing the size of the windings and hence, decreasing the heat losses beyond a certain figure, which is dependent on cost of copper, rate of interest, cost of power, runs the initial cost and hence the interest on investment up to a figure which offsets the gain in energy so secured. Hence the tendency in modern machines has been to go to higher and higher operating temperatures. The general practice today is to strike the balance at the point where the operating temperature is either 40 or 50 degrees above that of the surrounding air. Varnishes, gums and impregnating materials which are satisfactory at these temperatures are now in common use, and in fact, most of the better grade insulation will stand a much higher temperature for short periods.

The past twenty years have witnessed great increases in the voltages at which power is transmitted, and today 220,000 volts are in actual use. Such high voltages place a very heavy demand on the insulation materials of transformers and circuit breakers, as well as on line insulation. As a result of this increase in operating voltage, transformer oils have been steadily improved, not only in their insulating value when new and clean, but in the resistance to sludging and emulsification. In the matter of line insulators, the need for high grade porcelain has stimulated the ceramic engineer (who is after all a specialized chemical engineer) to produce porcelains which are denser, harder, and stronger than those of previous years. Uniform porcelain is now the rule, rather than the exception.

For some applications, wood strain insulators are desirable, but years of sad experience have convinced many of the electrical engineers of the impossibility of complete uniform impregnation of wood. However, within the last two or three years the chemical engineer has succeeded in impregnating sticks about three feet long and 2½ inches in diameter, with such uniformity that continuous soaking in water, with weekly withdrawals for tests at 200,000 volts, required eight months to produce a failure. These insulators are not only lighter and stronger than the porcelain type, but are unaffected by extremes of heat and cold, and are resistant to knocks and hard usage.

Synthetic resins of the bakelite type are widely used for insulation purposes and are particularly useful because of their versatility, since they may be used as cements for the production of laminated insulating material, such as micarta, as the binder in molded insulation as a varnish and in some cases as the clear hardened resin itself. This is a development which has not only been very profitable to its inventor, but has been a great boon to our industry. When bakelite first came out, it was freely prophesied that it would displace nearly all other insulating materials, but in spite of its general usefulness, it is still one out of many, rather than one alone.

Some of the most remarkable improvements in electrical design have been the result of careful metallurgical research on magnetic materials. Development of silicon steels for magnetic circuits has made possible reductions in losses of transformers of from two-thirds to three-quarters of the figure which was good practtice

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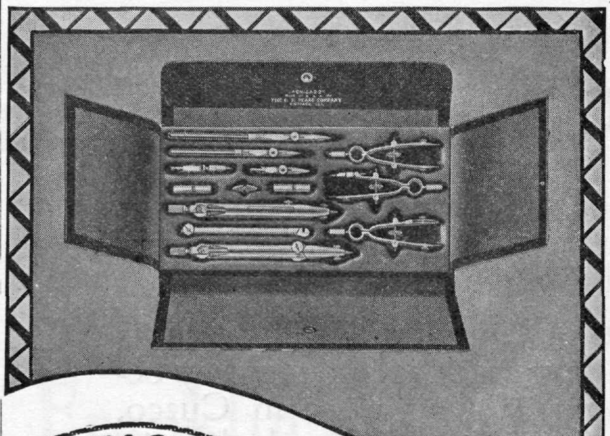

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twenty years ago. It is generally stated that the introduction of silicon steel cut the losses to one-half the previous value, and that refinements in the production and treatment cut these remaining losses in half. And here again, the chemical engineer is in constant close touch with the material, both during its manufacture, and in analysis after production. Due to the low carbon content of the silicon steels, great care must be exercised in the final annealing, as a reducing flame results in carburization, with consequent damage to the magnetic properties, and if the stacks are not carefully covered, an oxidizing flame will produce undue scaling. The chemist is always in demand when a slightly modified annealing furnace is started up, as his advice and comfort are greatly desired when the first batches turn out poorly. For applications, as radio transformers and loud speakers, iron-nickel alloys are used, and here the purity of the materials particularly in regard to sulphur and carbon is of such importance that electrolytic iron and nickel are used for melting stock, and in order to avoid contamination during melting, a zircon crucible is used, the melting being done in a high-frequency induction furnace. This makes a rather expensive alloy, but as those of you who are radio fans know, the best is none too good.

Just as the industry needs conductors of both very low resistance and very high resistance to current flow, it also needs not only the low-loss magnetic material mentioned above, but high loss, material for permanent magnets, so that when once magnets are made from it, they will retain their magnetization indefinitely. The iron-cobalt tungsten alloy has been under investigation for a number of years, and magnets made from it have such strength and permanence that they are very greatly superior to all others for use in small meters and in oscillographs. It is a remarkable thing to see a short magnet of this material holding a bar of steel twenty-five times its own weight.

The question of lubricants is one that is always of prime importance to any industry concerned in the manufacture of moving machinery. This is particularly the case with the electrical industry, where turbine generators run at high speeds and with emulsification to be guarded against. Motors are even more of a problem, as they not only cover a very wide range of sizes, speeds and bearing pressures, but must in many cases run under extremely adverse conditions of temperature, dust, fume, and moisture. In addition, the lubrication must be such that attention is limited to the minimum. These requirements result in the need of close attention to the quality of the lubricants employed and call for nice discrimination in choosing the oil or grease to be used with a given type of bearing. Lubrication of cutting tools presents an entirely different problem, and until recent years, the chemist had little to do with it, except to see that the lard oil was reasonably pure. Today emulsions of a lime soap with an oil and water are used almost exclusively in routine machine work, and here again the chemist shines, for the making of these emulsions, while usually done at some outside plant, is under close chemical control and the material itself subject to chemical inspection as purchased.

After the designer has finished with a piece of apparatus ,the question arises as to its protection from the atmosphere. He then turns to the chemical engineer for a finish. If the apparatus is to be used in a clean, protected place, paint, lacquer, or one of the varnish finishes may be chosen, but if designed for outdoor service, sherardizing, galvanizing, "Shoopizing," or

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cadmium plating may be recommended. In any event, the material and method of application will have been worked up either by one of the chemical engineers at the plant or selected as the result of the work of some chemist at a university or at another plant. In the Westinghouse Research Laboratory several years' work have been devoted to the process of cherardizing and the same is undoubtedly true of other organizations in the industry.

The process work of the electrical industry embraces the study and improvement of both mechanical and chemical processes, and in many cases, cannot be separated from the work on materials. An interesting case of this inter-relationship is in connection with the filament for radio tubes. For years, the majority of vacuum tubes were made with a tungsten filament—either pure or with a few per cent of thoria to prevent undue crystal growth and "offsetting" or breakage. The chemical engineers devised a way to get metallic thorium on the filament, and as a result we have the "thoriated filament" tube, a far more efficient affair than its predecessor of the same size with an ordinary tungsten filament. The making of this tube involves the following of a very definite process in changing some of the thoria to metallic thorium, and it is only by following the process specifications quite closely that the desired result is attained. When the Westinghouse Company decided to make the oxide coated filament tube, considerable difficulty was experienced in getting consistently good filament. The problem was turned over to one of our chemists who knew nothing of radio work, but who had had a wide experience with coatings for protection. He tried many methods of applying a coating and succeeded in getting several methods of making it stick, but none which were entirely satisfactory, until he tried a scheme which is so valuable it should be used more extensively. He exaggerated one of the factors which was harmful, carrying it to the limit and found what often happens, that this factor, undesirable in small amounts, was a very useful one if carried to extremes. With this as a basis, he developed a process which produces a filament having all the desired characteristics, and this process is still being followed.

A real and extremely important function of the chemical engineer is to keep an eye open for the problems and possibilities of tomorrow, and five or ten years from tomorrow. Vision which enables an organization to direct the research work into channels which may lead to useful results in the future, is one of the big needs of the industry. Fortunately, there is a great deal of this forward looking, but more is needed. The chemical engineer must also be able to view with equanimity the certainty that many of his researches will turn out badly, and that he may do large amounts of fundamental research which will find no useful commercial application. For example, all the large electrical companies as well as some of the oil refiners, have been working for years to find a reliable means of determining the tendency of a transformer oil to sludge. There have been many methods proposed, but none are satisfactory, and in the last analysis, the only method is that of the Yankee racing skipper who was asked if his craft would stand all the sail he was putting out, "try her." The remedy for such conditions, and for the occasional failure of the chemical engineer to secure the desired result, is more chemical engineers, and more effort. For it is a fact that the electrical industry is indebted to the chemical engineers for a very large share of its growth, and that the time and money spent by him has on the average, paid handsome dividends.